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Effect of Nano-DAP seed treatment and foliar spray on growth, yield attributes and yield of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted during *kharif*2022 at the Research Farm of Department of Agronomy. Experimental site falls under sub-temperate mid hill zone of Himachal Pradesh. It lies in North-West Himalaya in the Palam Valley of Kangra district of Himachal Pradesh, India. To study the Effect of Nano-DAP seed treatment and foliar spray on growth and yield of wheat (*Triticum aestivum* L.). The experiment was conducted in Randomized Complete Block Design with ten treatments, replicated three times. Application of recommended dose of fertilizers (120:60:30kg/ha) (T2) recorded highest plant height at 30, 60 days after germination while at 90, 120 and at harvest the taller plants height was absorbed in T8 (75% NP + seed treatment @5ml/kg seed + foliar spray @ 0.2% at 30 days after germination) highest numbers of tillers per meter square at 30 and at 30 DAS recorded in T2 while at 90, 120 and at harvest highest number of tillers/m^2 recorded in T8. Numbers of effective tillers/m^2 and No. of grains/spike and grain yield was absorbed in T8 while wheat test weight was recorded in T2 (recommended dose of fertilizers).

Keywords: Nano DAP, wheat, growth, yield attributes, yield

Introduction
Wheat (*Triticum aestivum* L.) is one of the most prevalent cereal crops in India, serving as a staple food for a vast majority of the population and contributing significantly to the agricultural economy (Ramadas *et al*., 2020) [13]. It is widely cultivated across the country, with the Indo-Gangetic Plains being the primary wheat growing region (Bhatt *et al*., 2021) [5]. However, the mid-hills of India, including Himachal Pradesh, also hold great potential for wheat cultivation due to their favorable agro-climatic conditions. In Himachal Pradesh, wheat is a key *rabi* crop that not only supports local food security (Satyarthi *et al*., 2018) [14] but also sustains the livelihoods of small and marginal farmers in the region (Devi and Kaur, 2022) [7].

With a total production of 103.6 million tonnes and a productivity of 3,533 kg/ha, wheat takes up 29.3 million hectares in India (Anonymous 2021a) [1]. 319 thousand hectares of wheat are grown in Himachal Pradesh, with a total production of 564.63 thousand tonnes (Anonymous 2021b) [2]. Chemical fertilizers are the mainstay of Indian agricultural production systems, but over the past few decades, the use efficiencies of N, P, and K fertilizers have stayed steady at 30–35%, 15-20%, and 35–40%, respectively. This has been attributed to a number of factors, including leaching, photolysis-induced degradation, hydrolysis, and volatilization, among others (Tarafdar *et al*. 2016) [18].

Most importantly, India currently imports significant quantities of fertilizer to meet domestic demand. The fertilizer market in India experienced a significant increase in imports during the year 2023, with a remarkable overall growth of 25% compared to the previous year (Anonymous 2023) [3]. Among the imported fertilizers, DAP, showed impressive growth rates of 52%, surpassing the imports recorded in the year 2022 (Anonymous 2023) [3]. In order to address issues of low fertiliser use efficiency, imbalanced fertilization, multi-nutrient deficiencies and decline of soil organic matter, it is indeed need of the day to evolve the nano-based fertilizer

formulations with multiple functions.

The newly created nano-fertilizer will reduce chemical fertilizer consumption 80–100 times, saving significant foreign exchange on fertilizer imports (Poudel *et al*. 2023) [11]. In India, Nano-DAP (Diammonium Phosphate) with size ranges from 10 to 30 nanometers were recently introduced by Indian Farmers Fertilizer Cooperative Limited (IFFCO) to meet the demands of farmers. It contains 8 per cent nitrogen and 16 per cent phosphorus by weight in its nano form. The finance minister in the Interim Budget 2024-25 has announced the expansion of the application of Nano-DAP as a fertilizer on various crops in all agro-climatic zones. As a part of the Union Government Aatma Nirbhar Bharat's initiative to promote self-sufficiency in fertilizers, it is advising and supporting the Indian fertilizer companies to strengthen their backend supply chain.

Materials and Methods

The experiment was carried out at the Research Farm of Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during *rabi* 2022-23. To study the effect of Nano-DAP seed treatment and foliar spray on growth of wheat (*Triticum aestivum* L.) The experimental Farm of Department of Agronomy is situated at 32º 06' N latitude, 76°54′ E longitude and at an altitude of 1290 m above mean sea level. Experimental site falls under sub-temperate mid hill zone of Himachal Pradesh. It lies in North-West Himalaya in the Palam Valley of Kangra district of Himachal Pradesh, India.

Soil of the experimental site was silty clay loam in texture, acidic in reaction, low in available nitrogen and medium in available phosphorus and available high in potassium content. The experiment was conducted in a Randomized Block Design (RBD) with ten treatments and three replications. The treatment details are as such; T_1: N_0P_0, T_2: $N_{100}P_{100}$, T_3: N_0 P_0 + Nano-DAP Seed treatment (ST) @ 5 ml / kg seed, T_4: N_0 P_0 + Nano-DAP Seed treatment (ST) @ 10 ml / kg seed, T_5: N_0 P_0 + Nano-DAP Foliar Spray (FS) @ 0.6% at 30 DAG, T_6 N_0 P_0 + Nano-DAP Seed treatment (ST) @ 5 ml / kg seed & Foliar Spray (FS) @ 0.6% at 30 DAG, T_7: N_{75} P_{75} + Nano-DAP Foliar Spray (FS) @ 0.2% at 30 DAG, T_8: N_{75} P_{75} + Nano-DAP Seed treatment (ST) @ 5 ml / kg seed & Foliar Spray (FS) @ 0.2% at 30 DAG, T_9: N_{50} P_{50} + Nano-DAP Foliar Spray (FS) @ 0.4% at 30 DAG and T_{10}: N_{50} P_{50} + Nano-DAP Seed treatment (ST)@ 5 ml / kg seed & Foliar Spray (FS) @ 0.4% at 30 DAG. Potassium recommended dose was used in all treatments. The RDF for wheat was 120:60:300 kg/ha and variety was used HPW-368. During the experimental period, the mean weekly maximum temperature ranged between 13.7°C in the 3rd standard week and 29.2°C in the 20th standard week. Furthermore, the total rainfall received during the cropping season was 483.1 mm.

The plant height of wheat was measured from the ground level to tip of the terminal growing point and expressed in cm. The progressive tiller count was recorded at 30, 60, 90 DAS and at harvest from two observational units of one meter row length, earmarked randomly in each net plot of experiment. The data so recorded was averaged and multiplied by factor 5 to get number of tillers per square meter.

Number of effective tillers per square meter was counted from two randomly selected meter row lengths from each net plot at the time of harvesting and the mean was calculated. This mean value was used to calculate the number of effective tillers per square meter by multiplying it with factor 5. Ten spikes were randomly selected from each plot and grains were manually threshed from the spikes and then the total number of grains was counted. The mean value of ten spikes was given as number of grains/spike.

A representative sample of grains was taken from the produce of each net plot and1000--grains were counted by digital seed counter. Moisture content in grains was recorded and the weight of 1000 grains adjusted at 14% moisture and expressed as 1000 grain weight in grams. Grain yield (q/ha) were measured by the total biomass harvested from each net plot was threshed, winnowed, cleaned and dried. Grains thus obtained were weighed in terms of kg/net plot and then converted in terms of q/ha. Data on various parameters were statistically analyzed using the method proposed by Gomez and Gomez (1984) [8]. The critical difference (CD) was calculated for parameters whose effects were significant at the 5% confidence level.

Results and Discussion

The application of Nano-DAP significantly affects the plant height at all stages of observation (Table 1). At 30 and 60 DAS, significantly taller wheat plants were recorded with the application of 100% NPK (T_2) though this treatment was at par with all other treatments in which 75% recommended NP was used along with seed treatment and foliar application of nano – DAP was applied. Nano spray effects were observed at later stages i.e., at 90 DAS, 120 DAS and at harvest (Table 1), because sprays were done at tillering stage. Significantly taller plants were recorded at 90,120 DAS and at harvest in T_8 i.e. 75% NP along with seeds treated with Nano–DAP and a foliar spray of Nano–DAP @ 0.2% at 30 DAG and though this treatment was at par with the application of 100% recommended NPK (T_2) as well as treatment 7 where 75% recommended NP was applied along with foliar application of Nano–DAP @0.2% at 30 days after germination. However, significantly lower plant height was recorded in control treatment at all stages of observations. Same finding was reported by (thakur *et al* 2024) [21].

High reactivity and surface area of Nano-particles helped in meeting the immediate need of nitrogen and phosphorus throughout the crop period, improved enzymatic activity of photosynthesis, carbohydrate metabolism, protein synthesis, cell division, and cell elongation and increased nutrient availability with the combined application of chemical and nano fertilizers could all contribute to the increase in plant height at 90, 120 DAS and harvest. These findings were in corroboration with the findings of Yasser *et al*. (2020) [20], Singh *et al*. (2021) [15].

Yield-determining characteristics include a crop's ability to tiller, which contributes to increased yields (thakur *et al* 2024) [21] Data pertaining to the effect of Nano-DAP application, both as seed treatment as well as foliar application on tiller count in wheat crop recorded at periodic intervals and at harvest has been given in Table 2.

At 30 DAS, significantly higher number of tillers were recorded with the application of 100% recommended dose of fertilizer (T_2) though the treatment was found to be at par with application of 75 and 50% of recommended NP application was supplemented with seed treatment with Nano-DAP as well as its foliar spray (T_8, T_7, T_{10}, T_9). Significantly lower number of tillers was recorded in the control treatment where no nitrogen and phosphorus were applied to the wheat crop (T_1). At 60, 90, 120 DAS and at harvest, significantly taller wheat plants were observed in the treatment where 75% of recommended NP was applied along with seeds treated with Nano–DAP and a foliar sprays of Nano–DAP @ 0.2% at 30 days after germination (DAG) and the treatment were at par with the treatments (T_2, T_7 and T_{10}). The treatments in which only potassium was added through conventional fertilizer (T_1) yielded significantly lower number of tillers per square meter.

Tiller buds grow in response of a combination of genetic traits

and growing conditions, most notably the quantity of nitrogen absorbed and carbohydrates created during the growth stages of the buds (Tanaka and Garcia 1965) [17]. Application of conventional fertilizer along with seed treatment with Nano-DAP might have resulted in better growth of tiller buds at initial growth stages. Furthermore, nitrogen application at later stages whether in terms of top dressing or foliar application of nitrogen through Nano-DAP increased the number of effective tillers with reduced mortality of tillers at later stages. Phosphorus being a component of ATP played a key role in various metabolic processes, ensured rapid translocation of photosynthates to the growing tiller buds, thereby, supported the growth of tiller buds and resulted in better tillering. Sorour *et al*. (2020) [16] and Maloth *et al*. (2024) [10] have also reported similar findings stating the positive impacts of combined application of conventional fertilizer along with the nano fertilizers on growth parameters of crop.

A close perusal of the data revealed that significantly higher number of effective tillers/m^2 were recorded with the application of 75% NP (T_8), remaining with at par with T_2 and T_7 (Table 3). Significantly lower effective tillers/m^2 was observed in control treatment. Adequate supply of nitrogen and phosphorus from conventional fertilizers along with seed treatment and foliar application of Nano-DAP might have increased the number of tillers and also reduced the number of barren tillers, hence ultimately increasing number of effective tillers / m^2 (Chinnappa *et al*. 2023) [6].

Number of grains / spike was significantly impacted by different treatments with application of 75% NP along with seed treatment with Nano-DAP 5ml/kg seed as well as its foliar spray at 30 DAG @ 0.2% (T_8) resulting in significantly higher number of grains / spike though this treatment was at par with application of 100% NP (T_2) and 75% NP + foliar spray of @0.2% (T_7). Control treatment where no nitrogen and phosphorus were applied to the wheat crop (T_1) recorded significantly lower number of grains/spike. Significantly higher values can be attributed to the fulfillment of adequate nutritional requirement of wheat crop, resulting in good growth of crop all through the growing season and hence higher number of grains/spike. Similar results were also obtained by Tomar *et al*. 2024 [19] in wheat.

1000-grain weight is basically an important yield attributing character contributing to overall yield of any crop. The data on the effect of different nitrogen and phosphorus levels with seed treatment and nano sprays on test weight has been given in Table 3.

Significantly higher value of 1000 – grain weight was observed with the application of 100% NP (T_2) though this treatment was at par with 75% NP along with seed treatment of 5ml/kg seed + foliar spray of Nano-DAP @ 0.2% at 30 DAG (T_8), treatments in which 75% NP application was supplemented with foliar application of @ 0.2% at 30 DAG (T_7) and (T_{10}) where 50%NP was applied along with seed treatment of Nano-DAP 5ml/kg seed along with a foliar spray of Nano-DAP at the rate of @ 0.2% at 30 DAG. Significantly lower 1000 – grain weight was observed in treatment in which no nitrogen and phosphorus was applied to the wheat crop (T_1).

Nitrogen, phosphorus and Potassium dosages have a major effect on wheat's 1000-grain weight. Grain filling is improved by enough NPK fertilization, which raises kernel weight. Grain development is aided by nitrogen, which is essential for the synthesis of proteins and chlorophyll. While potassium increases plant resilience and water management, phosphorus promotes root growth and energy transmission. According to research, by guaranteeing balanced nutrient intake, an ideal NPK ratio of 120:60:30 kg/ha raises 1000-grain weight (Joy *et al*., 2018) [9]. A balanced strategy is necessary because too much nitrogen can increase vegetative growth while also decreasing grain weight. Proper NPK management boosts wheat productivity and grain quality, contributing to food security.

The grain yield of wheat was significantly impacted by various treatments (Table 3) Significantly higher yield (38.51 q / ha) recorded in T_8 (75% NP + seed treatment 5ml/kg seed + foliar sprays @ 0.2%) though this treatment was at par with T_2 (100% NP), T_7 (75% NP + seed treatment + foliar sprays @ 0.2%). Significantly lower grain yield was recorded in the control plot (17.48 q / ha). A close perusal of the data revealed that simultaneous use of seed treatment along with a spray of Nano – DAP @ 0.2% at 30 days after germination resulted in significant increase in grain yield as compared to when only fertilizers were used. The optimum and balanced nutrient availability was ensured throughout the crop period, particularly during the critical stages of the crop, by applying conventional and nano fertilizer (nano DAP) in combination. This is because nanoparticles have a greater surface area and are smaller size, allowing them to more readily enter plants and improve nitrogen and phosphorus uptake. Increased uptake leads to optimal growth of plant parts and metabolic processes, such as photosynthesis, which increases the accumulation of photosynthates and their translocation to the economically productive parts of the plant. This process increase biomass, yield- attributing characters, and yield by enhancing the translocation of assimilates to seeds – all of which contribute to increased yield. Similar results were reported by Rajput *et al*. (2022) [12], Bhargavi and Sundari (2023) [4] and Thakur *et al* (2024) [21].

Table 1: Effect of Nano-DAP seed treatment and foliar spray on plant height of wheat at periodic interval

Sr. No.	Treatment	Plant height (cm)				
		30 DAS	60 DAS	90 DAS	120 DAS	At Harvest
T_1	N_0P_0	8.0	16.6	38.8	64.2	65.3
T_2	N_{100} P_{100}	13.2	25.2	55.9	85.6	90.1
T_3	N_0P_0 + Seed treatment (ST) Nano DAP @ 5 ml / kg seed	8.2	16.9	40.2	67.5	68.7
T_4	N_0P_0 + ST Nano DAP @ 10 ml / kg seed	8.3	17.2	42.2	68.7	69.9
T_5	N_0P_0 + Foliar spray (FS) Nano DAP @ 0.6% at 30 days after germination (DAG)	8.1	17.0	41.6	68.3	69.0
T_6	N_0P_0 + ST Nano DAP @ 5 ml / kg seed + FS Nano DAP @ 0.6% at 30 DAG	8.3	17.2	42.7	71.8	72.5
T_7	N_{75} P_{75} + FS Nano DAP @ 0.2% at 30 DAG	12.9	24.8	54.5	82.6	88.0
T_8	N_{75} P_{75} + ST Nano DAP @ 5 ml / kg seed + FS Nano DAP @ 0.2% at 30 DAG	13.0	25.0	56.3	85.7	90.8
T_9	N_{50} P_{50} + FS Nano DAP @ 0.4% at 30 DAG	12.7	24.0	52.2	79.7	82.6
T_{10}	N_{50} P_{50} + ST Nano DAP @ 5 ml / kg seed + FS Nano DAP @ 0.4% at 30 DAG	12.8	24.4	53.4	82.2	85.7
	S.Em±	0.2	0.8	1.3	1.6	1.6
	CD (P = 0.05)	0.6	2.3	3.9	4.7	4.8

Table 2: Effect of Nano- DAP seed treatment and foliar spray on No. of tillers (No./m^2) of wheat at periodic interval

Sr. No.	Treatment	No. of tillers (No./m^2)				
		30 DAS	60 DAS	90 DAS	120 DAS	At Harvest
T_1	N_0P_0	123.8	145.0	233.2	217.3	201.7
T_2	N_{100} P_{100}	136.4	230.4	330.5	315.4	304.0
T_3	N_0P_0 + Seed treatment (ST) Nano DAP @ 5 ml / kg seed	125.4	153.1	246.2	233.5	212.2
T_4	N_0P_0 + ST Nano DAP @ 10 ml / kg seed	125.6	160.2	253.6	242.6	226.4
T_5	N_0P_0 + Foliar spray (FS) Nano DAP @ 0.6% at 30 days after germination (DAG)	125.1	158.5	250.5	238.6	219.8
T_6	N_0P_0 + ST Nano DAP @ 5 ml / kg seed + FS Nano DAP @ 0.6% at 30 DAG	125.5	168.4	258.3	248.0	230.0
T_7	N_{75} P_{75} + FS Nano DAP @ 0.2% at 30 DAG	134.3	221.2	320.3	310.2	296.6
T_8	N_{75} P_{75} + ST Nano DAP @ 5 ml / kg seed + FS Nano DAP @ 0.2% at 30 DAG	134.8	232.2	333.5	317.8	308.8
T_9	N_{50} P_{50} + FS Nano DAP @ 0.4% at 30 DAG	131.2	198.2	290.2	279.3	263.1
T_{10}	N_{50} P_{50} + ST Nano DAP @ 5 ml / kg seed + FS Nano DAP @ 0.4% at 30 DAG	131.7	208.5	305.0	297.7	281.4
	S.Em±	3.6	8.0	10.1	9.6	9.3
	CD (P = 0.05)	10.7	24.0	30.2	28.8	28.0

Table 3: Effect of Nano-DAP seed treatment and foliar spray on yield attributes and yield of wheat

Sr. No	Treatments	No. of effective tillers per /m^2	No. of grains/spike	1000-grains weight (g)	Grain yield q/ha
1	N_0 P_0	185.0	32.2	39.16	17.48
2	N_{100} P_{100}	288.4	47.1	41.44	38.22
3	N_0 P_0 + Nano - DAP (ST) @ 5 ml / kg seed	203.4	33.9	39.68	19.46
4	N_0 P_0 + Nano - DAP (ST) @ 10 ml / kg seed	208.3	34.3	39.93	20.74
5	N_0 P_0 + Nano - DAP (FS) @ 0.6% at 30 DAG	201.7	34.4	39.74	20.54
6	N_0 P_0 + Nano – DAP (ST) @ 5 ml / kg seed & (FS) @ 0.6% at 30 DAG	211.6	35.3	40.16	22.22
7	N_{75} P_{75} + Nano – DAP (FS) @ 0.2% at 30 DAG	280.0	46.1	40.88	36.04
8	N_{75} P_{75} + Nano – DAP (ST) @ 5 ml / kg seed & (FS) @ 0.2% at 30 DAG	291.7	47.5	41.20	38.51
9	N_{50} P_{50} + Nano – DAP (FS) @ 0.4% at 30 DAG	256.7	42.2	40.48	31.90
10	N_{50} P_{50} + ST Nano – DAP @ 5 ml / kg seed & (FS) Nano DAP @ 0.4% at 30 DAG	265.0	43.1	40.66	33.38
	S.E(m±)	8.9	1.6	0.31	1.40
	CD (P=0.05)	26.5	4.8	0.92	4.15

Conclusion

The field experiment demonstrated that the combined application of chemical fertilizers along with Nano-DAP, particularly the 75% NP + seed treatment + a foliar sprays @ 0.2% significantly improved plant height, numbers of tillers per meter square, numbers of effective tillers/$m^{2,}$ numbers of grains/spike and 1000 grains weight of wheat. To maximize its incorporation into agricultural practices and guarantee sustainable crop production systems, more research is needed into the long-term impacts, economic viability, and environmental sustainability of Nano DAP.

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Conflict of Interest

There is no conflict of interest in this research paper.

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